

FORM PTO-1350  
(REV 10-2000)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

CU-2504 RJS

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)

09/831416

INTERNATIONAL APPLICATION NO.  
PCT/AU99/01000INTERNATIONAL FILING DATE  
12 November 1999PRIORITY DATE CLAIMED  
12 November 1998TITLE OF INVENTION  
LIGHT ROUTING WITH BRAGG GRATINGSAPPLICANT(S) FOR DO/EO/US  
John CANNING

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☒ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 16 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.  
☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☒ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:  
7 sheets of drawings

Express Mail Label No.:

L 698 180623

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17. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a)(1) - (5)) :

Neither international preliminary examination fee (37 CFR 1.482)  
nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO  
and International Search Report not prepared by the EPO or JPO ..... \$1000.00

International preliminary examination fee (37 CFR 1.482) not paid to  
USPTO but International Search Report prepared by the EPO or JPO ..... \$860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but  
international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$710.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)  
but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$690.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)  
and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$100.00

ENTER APPROPRIATE BASIC FEE AMOUNT = \$ 1000.00

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30  
months from the earliest claimed priority date (37 CFR 1.492(e)).

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	17 - 20 =	0	X \$18.00	\$
Independent claims	2 - 3 =	0	X \$80.00	\$

MULTIPLE DEPENDENT CLAIM(S) (if applicable) + \$270.00 \$

TOTAL OF ABOVE CALCULATIONS = \$ 1000.00

☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above  
are reduced by 1/2. \$

SUBTOTAL = \$ 1000.00

Processing fee of \$130.00 for furnishing the English translation later than ☐ 20 ☐ 30  
months from the earliest claimed priority date (37 CFR 1.492(f)). \$

TOTAL NATIONAL FEE = \$ 1000.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be  
accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property + \$ 40.00

TOTAL FEES ENCLOSED = \$ 1040.00

Amount to be

refunded: \$

charged: \$

a. ☒ A check in the amount of \$ 1040.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the above fees.  
A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
overpayment to Deposit Account No. 12-0400. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR  
1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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May 9, 2001

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REGISTRATION NUMBER

09/831416

JC08 Rec'd PCT/PTO 09 MAY 2001

DOCKET: CU-2504

**IN THE UNITED STATES PATENT & TRADEMARK OFFICE**

APPLICANT: John CANNING )  
 )  
TITLE: LIGHT ROUTING WITH BRAGG GRATINGS )  
 )  
COMPLETION OF PCT/AU99/01000 filed 12 November 1999 )

The Commissioner for Patents (DO/EO/US)  
Box PCT  
Washington, D.C. 20231

**PRELIMINARY AMENDMENT**

Dear Sir:

Please amend the application being filed herewith under 35 USC 371.

**IN THE CLAIMS:**

Please cancel all claims from the PCT application as filed as well as claims 1-17 from the claims filed in response to the Written Opinion on November 21, 2000 and substitute new claims 21-37 as attached to the substitute specification.

**REMARKS**

The aforesaid claims are based on the claims as filed in response to the Written Opinion in the PCT international application, with amendments to place the same in better condition for examination under U.S. rules of practice.

Examination of this U.S. application is requested to be based on the substitute specification enclosed herewith, which is based on the following materials:

### Field of the invention

### Background of the invention

The directing of light signals in different directions would also be desirable in devices where it is required to confine light to a predetermined path within the waveguide, for example in optical filter or optical resonator structures.

## Summary of the Invention

The present invention provides an optical waveguide structure comprising:

- an optical waveguide having a bend and being formed of a photosensitive material; and
- a grating structure arranged to guide light of a predetermined wavelength around the bend in the waveguide, the grating structure comprising UV-induced refractive index variations in the waveguide.

A substantial reduction in bending loss can be achieved by guiding light around the bend with the grating structure.

The present invention allows for angular dispersion to be added to a propagating light signal which can be controlled by the properties of the grating structures.

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For example, this can be utilised for dispersion compensation, pulse shirping, or pulse compressing. This is because different wavelengths see a different angular path with respect to the grating structure.

5       The device may be utilised in complex light manipulation circuits both in the spectral and time domain.

      The grating structure may comprise a chirped grating.

      The grating structure may be disposed to direct the light in a reflection or in a transmission mode.

10       Because of an angular dependence of the accepted wavelength in the grating, the device can depend on angular sweep to isolate wavelengths or signals.

      The grating structure may comprise a continuous grating. Alternatively, the grating structure may comprise  
15       two gratings which mirror each other.

      In one embodiment, the grating structure comprises regions of constant refractive index which extent in the propagation direction of the waveguide.

20       The regions may extend parallel to the propagation direction.

      The regions may extend cylindrically parallel to the propagation direction.

      The regions may extend ellipsoidally parallel to the propagation direction.

25       The device may further comprise at least one optical reflector disposed in a direction transverse to the propagation direction to aid in confining the light to the path.

30       The device may comprise two or more grating structures angularly disposed with respect to each other to guide light around the bend.

      Accordingly, different confinement conditions may be realised at different boundaries of the waveguide.

      The grating structures may be formed by UV-holography.

35       The gratings may be chirped gratings.

      The gratings may be sampled gratings.

AMEND

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The device may be a filter, a resonator, or a sensor.

In one embodiment, the device is a sensor further comprising means for measuring an intensity of the light at a predetermined point along the waveguide for determining  
5 changes in the intensity due to induced changes in confinement conditions of the sensor.

The changes may be induced by gas molecules entering the waveguide.

The present invention may alternatively be defined as  
10 providing a method of adapting a photosensitive waveguide to guide light of a predetermined wavelength around a bend in the waveguide, comprising:

- using UV light to induce refractive index variations in the waveguide such that at least one grating structure is  
15 formed, wherein the grating structure is disposed to guide the light around the bend.

Preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:  
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Brief Description of the Drawings

Figure 1 is a schematic drawing of a device embodying the present invention.

5 Figure 2 is a schematic drawing of a device embodying the present invention.

Figure 3 is a schematic drawing of a device embodying the present invention.

Figure 4 is a schematic drawing of a device embodying the present invention.

10 Figure 5 is a schematic drawing of a device embodying the present invention.

Figure 6 illustrates in an isometric view a method of fabricating a grating confined waveguide embodying the present invention.

15 Figure 7 illustrates in an isometric view another method of fabricating a grating confined waveguide embodying the present invention.

Figure 8 is a schematic drawing in a cross-sectional view illustrating a device embodying the present invention.

20 Figure 9 is shows a plot of resonant angle against grating period for a grating confined waveguide.

Figure 10 is a schematic drawing in an isometric view illustrating a device embodying the present invention.

25 Figure 11 is a schematic drawing in a top view illustrating a device embodying the present invention.

Figure 12 is a schematic drawing in a cross-sectional side view illustrating a device embodying the present invention.

30 Figure 13 is a schematic drawing in an isometric view of a resonator structure embodying the present invention.

Figure 14 is a schematic drawing in an isometric view of a device embodying the present invention.

Detailed Description of the Preferred Embodiments

35 Turning initially to Fig. 1, there is illustrated schematically a first example embodiment wherein a

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waveguide 1, down which light 2 is to be projected, undergoes a tight bend in the desired path. In the vicinity of the tight bend, a grating structure 4 is written. The grating structure 4 effectively has a photonic band gap preventing the effervescent light 2 from leaking out and resulting in higher efficiency in the light coupled to output 5. This results in a substantial reduction in the bending loss as a result of the utilization of the defraction grating 4 which in turn allows for tighter bends to be formed in the waveguide structure. The wavelength of the grating 4 can be tuned so as to match desired frequencies for operation.

Alternatively, as illustrated in Fig. 2, the grating 6 can be written in a reflection mode so as to provide for reflection of desired frequencies along the path 7 with losses 8 for those frequencies not having desired characteristics.

The utilization of the arrangement of Fig. 2 can be extended so as to provide for wavelength division multiplexing capabilities on a waveguide structure. This is illustrated in Fig. 3 wherein initial light can be launched down a waveguide having a number of frequencies  $\lambda_1, \lambda_2, \lambda_3$  coupled out of the waveguide by utilization of corresponding matched Bragg gratings 12, 13, 14 which operate so as to filter out the requisite frequencies.

Fig. 4 illustrates a further arrangement whereby light coupled along waveguide 15 will be coupled to outputs 16, 17 by means of suitably matched Bragg grating 18 having desired periodic characteristics, matched to the desired frequencies for coupling. The surrounding waveguide refractive index regions eg. 19 can be tapered to provide for stronger coupling. Preferably, the splitter arrangement of Fig. 4 has a Bragg grating coupled such that 50% of the light traverses along each of path 17, 18. This can be achieved for wavelengths twice the Bragg period. Of course, it is possible to adjust the Bragg period to adjust the output angle and coupling efficiency.



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Similarly, in Fig. 5 a Bragg grating 20 is provided for coupling around a bend for light travelling along the path 21, 22.

5 In Figure 6, a waveguide 110 in the form of a layer of photosensitive material has been deposited onto a substrate 112, eg. a silicon wafer having a native oxide layer for optical isolation of the waveguide material 110.

A UV beam 116 from a UV source 114 is focussed  
10 (through optical elements 118) in the plane of the waveguide 110. The substrate 112 can be laterally moved as indicated by arrows 120 and 122 to effect writing of planes indicated by lines 124 of a first grating 126 of a grating structure 127, through UV-induced changes of the refractive  
15 index of the waveguide 110.

After completion of the first grating 126, a second grating 128 of the grating structure 127 is written by appropriate moving of the substrate 112.

Light of a predetermined wavelength entering the  
20 waveguide 110 at predetermined angles of incidence on the gratings 126, 128 are confined to a path extending in the propagation direction 130 in the plane of the waveguide 110. The propagation characteristics of the waveguide 10 will therefore depend on the wavelength of a light signal  
25 131 and an angle  $\theta$  under which it enters the waveguide 110.

It is noted here, that in the planar structure described above the grating confinement is limited to one-dimension in the plane of the waveguide 110. However, it will be appreciated that waveguides can be produced in a  
30 photosensitive waveguide material that are grating confined in two or three dimensions.

For example, as illustrated in Figure 7, holographic UV grating writing techniques using a phase mask 140 can be used to produce a waveguide 142 (propagation direction as  
35 indicated by arrow 141) within a block 144 of

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photosensitive waveguide material which is grating confined in two dimensions through gratings 146, 148 of a first grating structure 147 and gratings 150, 152 of a second grating structure 151 respectively.

5 It is noted that the one or more of the grating structures of a device could alternatively comprise a continuous grating whilst still effecting confinement of light of a predetermined wavelength entering at a predetermined angle of incidence on the grating structure.

10 E.g. the resonator 250 shown in Figure 14 comprises two continuous grating structures 252, and 254 to effect channelling of light 256 of a predetermined wavelength entering the resonator 250 at a predetermined angle of incidence on the grating structures 252 and 254 around a  
15 ring path 258.

Grating confinement can also be achieved in an optical fibre, e.g. using a cylindrical grating structure 320 around a guiding core 322 (propagation direction perpendicular to the drawing plane) of an optical fibre 324  
20 as illustrated in Figure 12. The grating structure 320 effects confinement to a path extending in the propagation direction of light of a predetermined wavelength entering at a predetermined angle of incidence on the grating structure 320.

25 It will be appreciated by a person skilled in the art that for a non-cylindrical grating structure confinement conditions can vary in different radial directions.

The underlying principle of grating confined waveguide propagation is the Bragg condition. For a ray travelling  
30 in a medium of index  $n$ , peak reflectivity occurs when the wavelength  $\lambda$  satisfies:

$$\lambda = 2n\Lambda \sin \theta / m \quad (1)$$

where  $m$  is the diffraction order of the grating and  $\theta$  is the angle of the ray with respect to a single groove of the grating. This single equation contains within it the  
35

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entire properties of grating confinement such as e.g. so-called photonic crystal fibres.

Figure 8 shows the plot of resonant angle against grating period for the wavelength regime 1200-1600 nm for 1st, 2nd and 3rd order grating diffraction. At longer periods, variations in the resonant angle converge to within a few degrees, although the effect is largest for the 1st order. The physical interpretation is that for a large number of wavelengths the incident angle is approximately the same equating with similar diffraction properties. Therefore grating confinement will occur over a large bandwidth for a small input coupling angle at longer periods under identical launch conditions. Outside this regime radiation loss will occur.

Other interesting properties are noted. There exist other regimes of incident angle at which total internal reflection can occur to enable propagation along the grating confined waveguide. Light coupled into higher diffraction orders at much larger incident angles can also satisfy the Bragg relation, giving rise to higher order bandgaps. The effective coupling strength is reduced for higher order mode propagation in these regimes and is therefore characterised by larger mode areas. Since the effective index is different, it is possible to have fundamental-like mode behaviour simultaneously with different propagation properties. Thus e.g. photonic fibres have interesting launch regimes which are unlike conventional effective index fibres. These regimes exist because there are angular photonic bandgaps at which light cannot propagate through the surrounding grating cladding. Further, these bandgaps are robust and do not change much in angular properties with increasing period and will therefore be relatively insensitive to bend loss at longer periods.

The angular photonic bandgap is described by the angular reflectivity of the grating. This reflectivity bandwidth can be extremely small, depending upon the dimensions of the grating, its coupling coefficient, and the angle of incidence. For either normal (incident angle,  $\theta = 90^\circ$ ) or angled incidence, the power reflectivity is given from coupled mode theory as

$$R = \left| \frac{K \sinh SL}{S \cosh SL + i \Delta \beta \sinh SL} \right|^2 \quad (2)$$

where

$$S = \sqrt{K^2 - (\Delta \beta)^2} \quad (3)$$

K is the angle-dependent coupling coefficient for the grating, L is the length of the grating and  $\Delta \beta$  is the detuning of the wavevector, defined by

$$\Delta \beta = \frac{m\pi}{\Lambda} - \frac{2\pi}{\lambda} \sin \theta \quad (4)$$

Peak reflectivity occurs for  $\Delta \theta = 0$  and declines as  $\Delta \theta$  exceeds the magnitude of K. It is readily shown in grating confined waveguides that the angular acceptance of the reflectivity narrows considerably, with deviation away from near normal incidence (as indicated by the decreasing slope of Figure 8). Consequently, the higher order photonic bandgaps will be broader and less spatially selective and this may have implications for the robustness of singlemode operation for large input angles. The variation of detuning  $\delta(\Delta \beta)$  with angle  $\delta \theta$  is easily calculated from above:

$$\frac{\delta(\Delta \beta)}{\delta \theta} \approx -\frac{2\pi}{\lambda} \cos \theta \quad (5)$$

From this sensitivity to the capture angle it is possible to vary the angular dispersion significantly by appropriate selection of the period. Since the angle of incidents are similar at longer periods (Figure 8) the

Note that even for light guided solely under the effective index picture when the core index is higher than the surrounding cladding, unless the mode vector has an angle resonant with that of the grating, light can quickly couple to radiation modes and leak out. Further, this intolerance to the mode angle gives rise to the high spatial selectivity of these angular bandgaps such that single-moded propagation is robust especially for long grating periods. The mode profiles that are supported will therefore resemble the geometric positioning of the gratings radially around the core region and should differ from conventional waveguide guidance where such strict restrictions do not exist.

By recognising the importance of diffraction in a periodic lattice it is easily shown that grating confined propagation is readily achieved in so-called photonic crystal fibres. Further, the associated angular photonic bandgaps are responsible for a range of phenomena that distinguish these fibres from conventional effective index fibres. Extending the applications to resonators made up of these fibres, very interesting behaviour is predicted to occur as a result of the strict vector angles of the propagating modes, including ring-like resonances when the end reflectors are tilted. The polarisation properties of such structures may also differ to conventional resonators and an entire new class of passive and active filters and resonators are possible.

In Figure 9, a resonator 181 can be utilised for WDM (wavelength division multiplexing) filtering if the grating periods (which may be chirped) of gratings 182 and 184 of a first grating structure 183 and of gratings 186 and 188 of

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a second grating structure 187 are carefully selected such that a ring resonance is different for different wavelengths and therefore the outputs are spatially at different points. This is schematically illustrated by  
5 paths 190, 192 and example outputs 194, 196. The grating structures 183 and/or 187 may be sampled grating structures.

Complex design with the use of sampled profiles etc. can be used to achieve WDM operation. In particular the  
10 angular dependence means that it may be possible to get much more closely spaced peaks with higher contrast than conventional normal incidence. It is noted that this is also applicable to fibre (e.g. photonic crystal fibres) geometries.

As illustrated in Figure 10, in a resonator laser design 300 a photonic crystal fibre 302 is located in line  
15 in a ring laser 304 (of any sort) to improve both linewidth, laser stability and mode selectivity (including transverse if multi-mode active fibre is used to increase  
20 power). It is noted that a similar design can be applicable to linear lasers (of any sort).

As illustrated in Figure 11, in an alternative embodiment, a helical ring fibre laser 310 comprises an  
optical fibre 312 having a grating confined core structure  
25 314 and spaced apart concave reflectors 315, 316 within the core structure 314. The helical ring fibre laser 310 can thus provide a circularly birefringent output (as indicated by arrow 311).

Furthermore, high power fibre lasers may be provided  
30 without using cladding pump configuration. For such lasers, single mode operation and good stability are possible, as well as large mode areas. In such embodiments, the modes are grating diffraction dependent unlike conventional fibres which are aperture diffraction dependent.

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It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of  
5 the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

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The claims defining the invention are

1. An optical waveguide structure comprising:
  - an optical waveguide having a bend and being formed of a photosensitive material; and
  - 5       - a grating structure arranged to guide light of a predetermined wavelength around the bend in the waveguide, the grating structure comprising UV-induced refractive index variations in the waveguide.
- 10       2. An optical waveguide structure as claimed in claim 1, wherein the grating structure comprises a chirped grating.
- 15       3. An optical waveguide structure as claimed in either claim 1 or claim 2, wherein the grating structure comprises a sampled grating.
- 20       4. An optical waveguide structure as claimed in any one of the preceding claims, wherein the grating structure is disposed to guide the light in a reflection mode.
- 25       5. An optical waveguide structure as claimed in any one of the preceding claims, wherein the grating structure is disposed to guide the light in a transmission mode.
- 30       6. An optical waveguide structure as claimed in any one of the preceding claims, wherein the bend comprises a bend at a branched section of the waveguide.
7. An optical waveguide structure as claimed in claim 1, wherein the grating structure comprises a continuous grating.
8. An optical waveguide structure as claimed in any one of the preceding claims, wherein the grating structure comprises two gratings which mirror each other.
9. An optical waveguide structure as claimed in any one of the preceding claims, wherein the grating structure includes regions of constant refractive index which extend in a propagation direction of the waveguide.



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10. An optical waveguide structure as claimed in claim 9, wherein the regions extend parallel to the propagation direction.

5 11. An optical waveguide structure as claimed in claim 10, wherein the regions extend cylindrically parallel to the propagation direction.

12. An optical waveguide structure as claimed in claim 10, wherein the regions extend ellipsoidally parallel to the propagation direction.

10 13. An optical waveguide structure as claimed in any one of the preceding claims, wherein the device further comprises at least one optical reflector disposed in a direction transverse to a propagation direction of the waveguide to aid in guiding the light around the bend.

15 14. An optical waveguide structure as claimed in any one of the preceding claims, wherein the device comprises two or more grating structures angularly disposed with respect to each other to guide the light around a plurality of bends in the waveguide.

20 15. An optical waveguide structure as claimed in any one of the preceding claims, wherein each grating structure is formed by UV-holography.

25 16. An optical waveguide structure as claimed in any one of the preceding claims, wherein the waveguide structure is a sensor further comprising means for measuring an intensity of the light at a predetermined point along the waveguide for determining changes in the intensity due to induced changes in confinement conditions of the sensor.

30 17. A method of adapting a photosensitive waveguide to guide light of a predetermined wavelength around a bend in the waveguide, comprising:

- using UV light to induce refractive index variations in the waveguide such that at least one grating structure  
35 is formed, wherein the grating structure is disposed to guide the light around the bend.

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**I CLAIM:**

21. An optical waveguide structure comprising:  
an optical waveguide having a bend and being formed of a photosensitive material; and  
a grating structure arranged to guide light of a predetermined wavelength around the bend in the waveguide, the grating structure comprising UV-induced refractive index variations in the waveguide.
22. An optical waveguide structure as claimed in claim 21, wherein the grating structure comprises a chirped grating.
23. An optical waveguide structure as claimed in claim 21, wherein the grating structure comprises a sampled grating.
24. An optical waveguide structure as claimed in claim 21, wherein the grating structure is disposed to guide the light in a reflection mode.
25. An optical waveguide structure as claimed in claim 21, wherein the grating structure is disposed to guide the light in a transmission mode.
26. An optical waveguide structure as claimed in claim 21, wherein the bend comprises a bend at a branched section of the waveguide.
27. An optical waveguide structure as claimed in claim 21, wherein the grating structure comprises a continuous grating.
28. An optical waveguide structure as claimed in claim 21, wherein the grating structure comprises two gratings which mirror one another.
29. An optical waveguide structure as claimed in claim 21, wherein the grating structure includes regions of constant reflective index which extend in a propagation direction of the waveguide.
30. An optical waveguide structure as claimed in claim 29, wherein the regions extend parallel to the propagation direction.
31. An optical waveguide structure as claimed in claim 30, wherein the regions extend cylindrically parallel to the propagation direction.
32. An optical waveguide structure as claimed in claim 30, wherein the regions extend ellipsoidally parallel to the propagation direction.

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33. An optical waveguide structure as claimed in claim 21, wherein the device further comprises at least one optical reflector disposed in a direction transverse to a propagation direction of the waveguide to aid in guiding the light around the bend.

34. An optical waveguide structure as claimed in claim 21, wherein the device comprises two or more grating structures angularly disposed with respect to each other to guide the light around a plurality of bends in the waveguide.

35. An optical waveguide structure as claimed in claim 21, wherein each grating structure is formed by UV-holography.

36. An optical waveguide structure as claimed in claim 21, wherein the waveguide structure is a sensor further comprising means for measuring an intensity of the light at a predetermined point along the waveguide for determining changes in intensity due to induced changes in confinement conditions of the sensor.

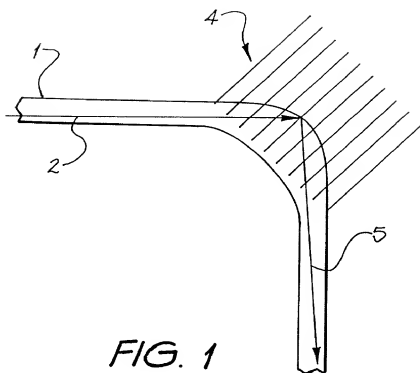
37. A method of adapting a photosensitive waveguide to guide light of a predetermined wavelength around a bend in the waveguide, comprising:

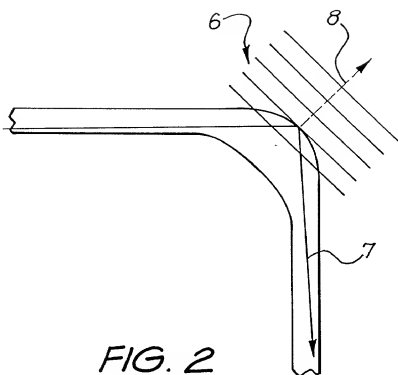
using UV light to induce refractive index variations in the waveguide such that at least one grating structure is formed, wherein the grating structure is disposed to guide the light around the bend.

**ABSTRACT**

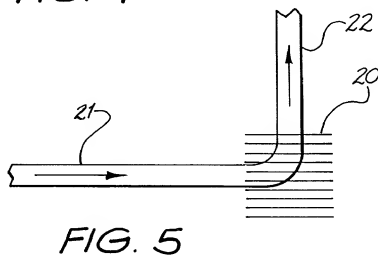
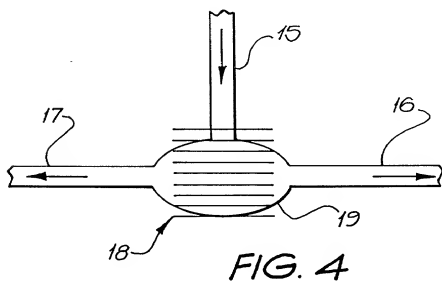
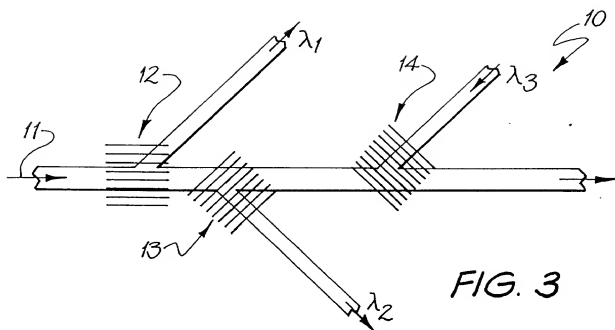
An optical device comprising a waveguide structure, at least one grating structure formed in the waveguide structure, and the grating structure being disposed to direct along a selected path in the waveguide structure light of a predetermined wavelength entering the waveguide structure at a predetermined angle of incidence to the grating structure.

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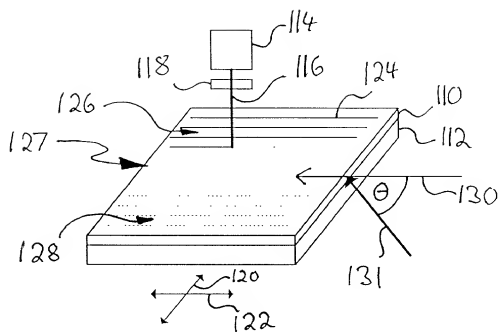


Figure 6

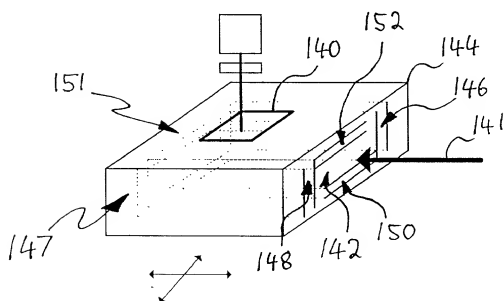


Figure 7



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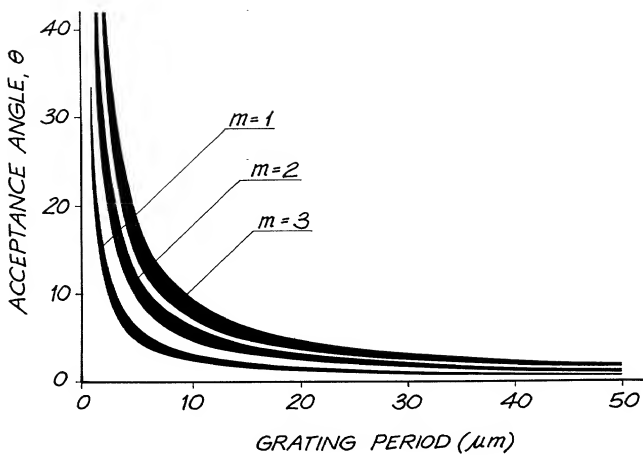


FIG. 8

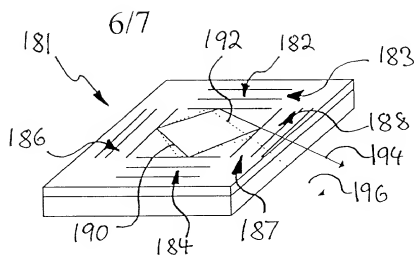


Figure 9

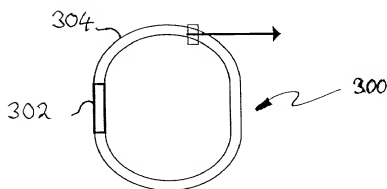


Figure 10

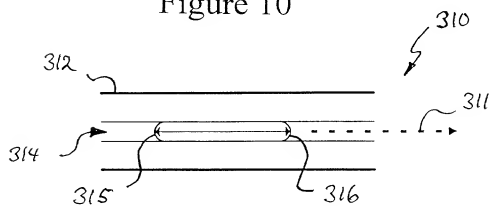


Figure 11

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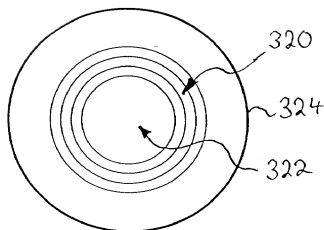


Figure 12

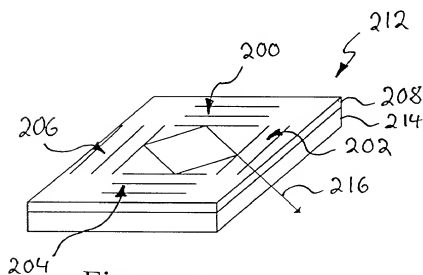


Figure 13

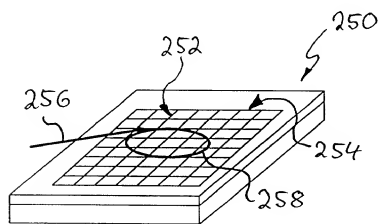


Figure 14

**CLAIM FOR BENEFIT OF PRIOR U.S. PROVISIONAL APPLICATION(S)**  
**(34 U.S.C. § 119(e))**

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

PROVISIONAL APPLICATION NUMBER	FILING DATE

**ALL FOREIGN APPLICATION(S), IF ANY, FILED MORE THAN 12 MONTHS**  
**(6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION**

*Note: If the application filed more than 12 months from the filing date of this application is a PCT filing forming the basis for this application entering the United States as (1) the national stage or (2) a continuation, divisional, or continuation-in-part, then also complete ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR CIP APPLICATION for benefit of the prior U.S. or PCT application(s) under 35 U.S.C. § 120.*

**POWER OF ATTORNEY**

I hereby appoint the following practitioner(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (*list name and registration number*).

Thomas F. Peterson, 24790; Richard J. Streit, 25765; Donald P. Reynolds, 26220; W. Dennis Drehkoff, 27193; Vangelis Economou, 32341; Brian W. Hameder, 45613; Paul B. West, 18947; Joseph H. Handelman, 26179; Peter D. Galloway 27885; John Richards, 31503; Iain C. Baillie, 24090; Richard P. Berg, 28145

- ☐ Attached, as part of this declaration and power of attorney, is the authorization of the above-named practitioner(s) to accept and follow instructions from my representative(s).

**SEND CORRESPONDENCE TO:**

Thomas F. Peterson  
 c/o Ladas & Parry  
 224 South Michigan Avenue  
 Suite 1200  
 Chicago, Illinois 60604

**DIRECT TELEPHONE CALLS TO:**

(Name and telephone number)

(312) 427-1300

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**DECLARATION**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

100831416-050901

**SIGNATURE(S)**

*Note: Carefully indicate the family (or last) name, as it should appear on the filing receipt and all other documents.*

**Full name of sole inventor**John

(Given Name)

(Middle Initial or Name)

CANNING

(Family (or Last) Name)

**Inventor's signature**Date 18 April 2001 Country of Citizenship AustraliaResidence Carlton NSW, AustraliaPost Office Address 10 Francis Street, Carlton NSW 2218, Australia

L 698 180623

Docket: CU-2504

PATENT

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**COMBINED DECLARATION AND POWER OF ATTORNEY***(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL,  
CONTINUATION OR CIP)*

---

As a below named inventor, I hereby declare that:

**TYPE OF DECLARATION**This declaration is of the following type: *(check one applicable item below)*

- ☐ original  
☐ design  
☐ supplemental

*Note: If the Declaration is for an International Application being filed as a divisional, continuation or continuation-in-part application, do not check next item; check appropriate one of last three items.*

- ☒ national stage of PCT

*Note: If one of the following 3 items apply, then complete and also attach ADDED PAGES FOR DIVISIONAL, CONTINUATION OR CIP.*

- ☐ divisional  
☐ continuation  
☐ continuation-in-part (CIP)

**INVENTORSHIP IDENTIFICATION**

**WARNING:** *If the inventors are each not the inventors of all the claims, an explanation of the facts, including the ownership of all the claims at the time the last claimed invention was made, should be submitted.*

My residence, post office address and citizenship are as stated below, next to my name. I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter that is claimed, and for which a patent is sought on the invention entitled:

**TITLE OF INVENTION**

---

**LIGHT ROUTING WITH BRAGG GRATINGS**

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**SPECIFICATION IDENTIFICATION**the specification of which: *(complete (a), (b) or (c))*

- ☐ (a) is attached hereto.

the specification of which: (complete (a), (b) or (c))

- ☐ (a) is attached hereto.
- ☐ (b) was filed on \_\_\_\_\_ as ☐ Serial No. \_\_\_\_\_ or ☐ Express Mail No. (as Serial No. not yet known) \_\_\_\_\_ and was amended on \_\_\_\_\_ (if applicable).

*Note: Amendments filed after the original papers are deposited with the PTO that contain new matter are not accorded a filing date by being referred to in the Declaration. Accordingly, the amendments involved are those filed with the application papers or, in the case of a supplemental Declaration, are those amendments claiming matter not encompassed in the original statement of invention or claims. See 37 CFR 1.67.*

- ☒ (c) was described and claimed in PCT International Application No. PCT/AU99/01000 filed on 12 November 1999 and as amended under PCT Article 34 on 21 November 2000.

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**ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR**

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information, which is material to patentability as defined in 37, Code of Federal Regulations, § 1.56,

*(also check the following items, if desired)*

- ☐ and which is material to the examination of this application, namely, information where there is a substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent, and
- ☐ in compliance with this duty, there is attached an information disclosure statement, in accordance with 37 CFR 1.98.

**PRIORITY CLAIM (35 U.S.C. § 119(a)-(d))**

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

*(complete (d) or (e))*

- ☐ (d) no such applications have been filed.
- ☒ (e) such applications have been filed as follows.

*Note: Where item (e) is entered above and the international application which designated the U.S. itself claimed priority check item (e), enter the details below and make the priority claim.*

**PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS  
(6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION  
AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119(a)-(d)**

COUNTRY (OR INDICATE IF PCT)	APPLICATION NUMBER	DATE OF FILING (day/month/year)	PRIORITY CLAIMED UNDER 35 USC 119	
Australia	PP 7168	12 November 1998	<input checked="" type="checkbox"/> YES	NO <input type="checkbox"/>
Australia	PQ 2503	27 August 1999	<input checked="" type="checkbox"/> YES	NO <input type="checkbox"/>
			<input type="checkbox"/> YES	NO <input type="checkbox"/>

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			<input type="checkbox"/> YES	NO <input type="checkbox"/>
			<input type="checkbox"/> YES	NO <input type="checkbox"/>

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